

DESIGN GUIDANCE FOR GROUND WATER/FUEL EXTRACTION
AND GROUND WATER INJECTION SYSTEMS

Purpose. This design guide (DG) provides guidance for the basic design, installation and operation of ground water extraction and ground water injection systems for the cleanup of contaminated ground water, exclusive of any treatment systems. General guidance on ground water extraction (GWE) already exists (see references below). The intent of this DG is to document lessons learned from experience and to provide a systematic approach to the installation, operation and trouble-shooting of systems. In addition, this DG identifies aspects of ground water/fuel extraction and ground water injection systems that have led to poor performance and provides solutions to these problems. The DG provides trouble-shooting charts that list problems, causes, solutions and preventative measures. The DG then provides a series of checklists for the user to follow during the implementation of a project. The checklists identify information and data needs that, when addressed, greatly improve the likelihood for project goals to be achieved.

Applicability. This DG applies to all HQUSACE elements, major subordinate commands (MSC), districts, laboratories, and field operating activities (FOA) responsible for HTRW remediation projects. The engineering and design procedures are applicable to all Corps of Engineers projects. If required, ground water cleanup is conducted at both Federal and commercial sites, including Department of Defense installations. This DG was written for single and multi-well systems related to the cleanup of ground water and light non-aqueous phase liquids (LNAPLs).

References. This DG should be used in conjunction with the following USACE suggested design guidance documents (EM 200-1-2, EM 200-1-3, EM 1110-1-4000, ER 385-1-92, ER 1110-1-263, ER 1110-345-720, ER 1110-345-10028, ER 1165-2-13226, OM 25-1-51, TM 5-813-1). Required and related publications are listed in Appendix A.

Discussion. Appendix B represents the procedures and considerations associated with the design and trouble-shooting of ground water extraction and injection systems. It contains checklists and flow charts to be used investigation, characterization, design, and operation of a ground water cleanup project. Appendix C provides a list of acronyms throughout this DG.

Action. Each U.S. Army Corps of Engineers design element will be responsible for incorporating guidance into HTRW or military construction designs. This DG will be considered as the design guidance for ground water extraction units, exclusive of any treatment systems.

Implementation. This information is furnished to assist designers and operators in avoiding past problems in design and operation of new and/or retrofitted facilities used to extract, convey and inject treated water into the ground. Information presented herein is in addition to USACE EM 1110-1-4000, Monitoring Well Design, Installation, and Documentation at HTRW Sites. Use of the DG is not limited to HTRW, Civil Works or Military Construction.

1.0 GENERAL CHARACTERISTICS OF A GROUND WATER/FUEL EXTRACTION AND GROUND WATER INJECTION PROJECT

The purpose of this chapter is to familiarize the reader with the elements common to most extraction and injection projects.

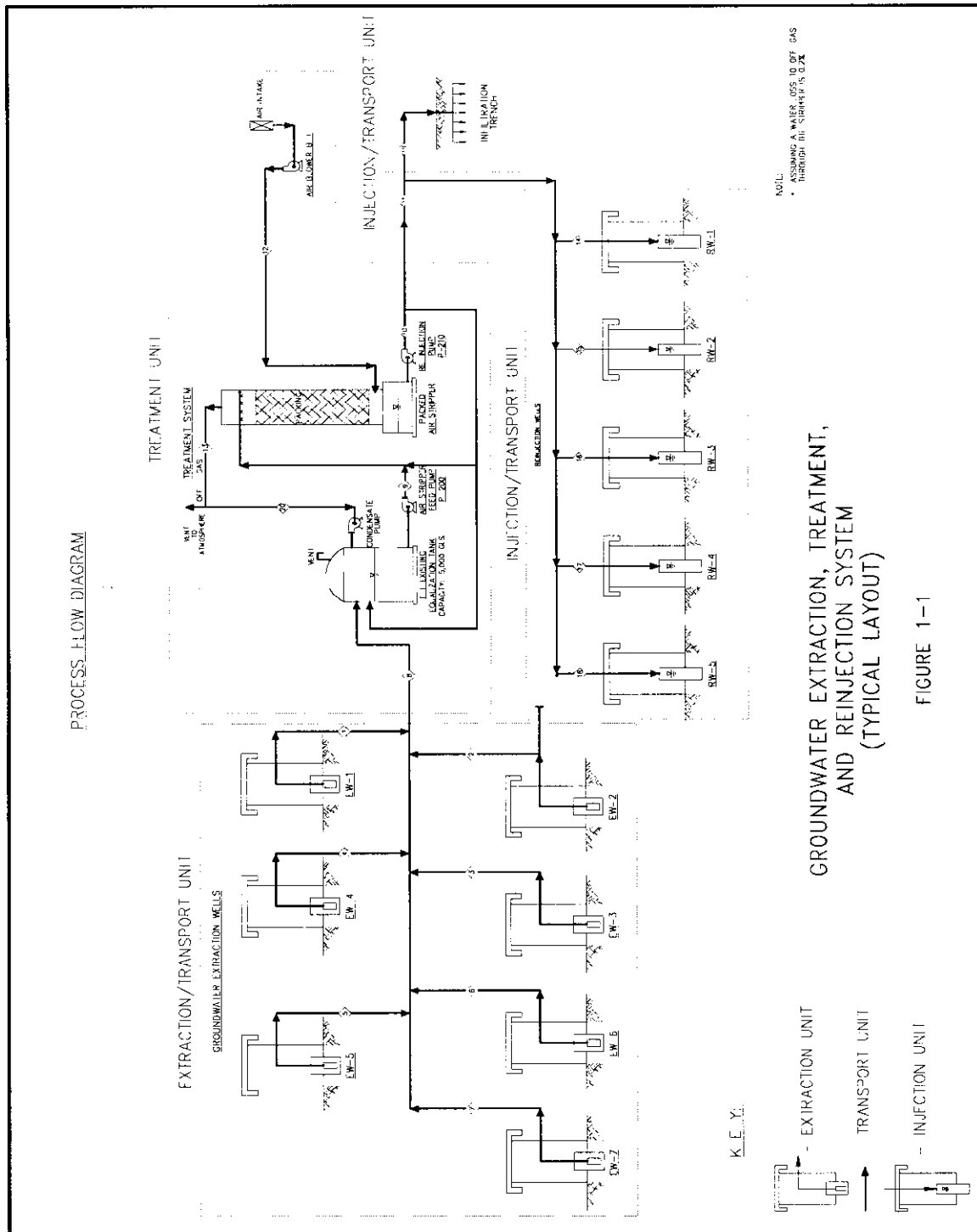
1.1 Introduction This chapter describes the components and phases of a typical ground water and fuel extraction and ground water injection project. This chapter also defines regulatory considerations, personnel and skills needed to undertake such a project. A common system configuration is illustrated and explained.

1.2 Extraction and Injection System A typical ground water extraction, treatment and injection system is designed to function as an integrated unit in which the proper operation of one component is dependent on the proper operation of the other components. While the system may function if some of the extraction or injection wells malfunction, performance goals may not be achieved.

The extraction, transport, treatment and injection system is considered a single unit. However, for the purpose of this DG, the system is subdivided into major components. Those components are the extraction unit, the transport unit, the treatment unit (not covered in this DG), and the injection unit. Figure 1 illustrates a typical system.

The extraction unit includes wells, well fields or trenches to remove contaminated ground water or light non-aqueous phase liquids (LNAPLs). The extraction unit includes pumps or other mechanisms used to bring fluids to the surface.

The transport unit includes piping from the extraction unit to the treatment unit, piping within the treatment unit, and piping to the injection unit.



GROUNDWATER EXTRACTION, TREATMENT,
AND REINJECTION SYSTEM
(TYPICAL LAYOUT)

FIGURE 1-1

Key issues to consider when selecting, designing and operating the transport unit include pipe sizing, pipe material compatibility and climatic considerations such as freeze protection and expansion allowances. Pipe issues are covered in EM 1110-1-4008.

The treatment unit is used to reduce contaminant concentrations to levels which are acceptable for disposal or injection. Discussion of treatment technologies is beyond the scope of this DG.

The injection unit, like the extraction unit, can include wells or trenches to dispose of treated ground water, to accelerate cleanup through enhanced flushing of the saturated zone, and to create hydraulic barriers to prevent further migration of contaminant plumes. The water is injected either by gravity feed or under pressure. Because of the injection role in influencing the direction of ground water movement, the proper location of injection points is critical.

1.3 Project Phases Ground water remediation projects generally begin with a preliminary site investigation to determine the presence of known or suspected contamination. Once contamination is confirmed to exceed acceptable levels, a ground water remediation project may be implemented. Ground water remediation projects can be subdivided into phases, each of which has clear goals, a schedule and specific activities. For the purposes of this DG, ground water remediation projects are subdivided into the following five phases:

- Remedial Investigation/Feasibility Study
- Design
- Construction
- Startup
- Operation/Maintenance

1.3.1 Remedial Investigation/Feasibility Study Phase The term Remedial Investigation (RI) is used by the USEPA to describe investigations at Comprehensive Environmental Response Compensation and Liability Act (CERCLA) sites. The comparable term used by the USEPA for Resource Conservation Recovery Act (RCRA) sites is a RCRA Facility Investigation (RFI). Objectives of the RI/FS are as follows:

- estimate the types and extent (present and future) of dissolved ground water contamination;
- estimate the volume and extent (present and future) of LNAPL (if any);

- collect sufficient physical and chemical measurements of geologic materials to allow choice of appropriate remedial technologies.

The RI is used to define the nature and extent of the problem, support risk assessment to define remedial goals and provide a baseline of information to allow comparison of remedial alternatives. Key RI and RFI guidance documents are as follows (Refer to Appendix A, References, Section A-1.c for full citation.) USEPA (OSWER Directive 9355.3-01), 1988, USEPA 540/G-87/004 (OSWER Directive 9355.0-7B), 1987, and USEPA 530/SW-89/031 (NTIS#PB89-200299), (OSWER Directive 9502.00-6D), 1989.

The term Feasibility Study (FS) is used by the USEPA to describe comparison of remedial alternatives for CERCLA sites. The comparable term used by the USEPA for RCRA sites is a Corrective Measures Study (CMS). Objectives of the FS are as follows:

- define cleanup goals, points of compliance and performance criteria for remedial systems; and
- develop a list of applicable alternatives;
- compare, choose and conceptually specify the most appropriate combination of extraction transport, treatment and injection (if applicable) techniques.
- prepare a list of data, based on selected remedial technology, to be obtained during the FS or design phase for detailed design.
- Frequently models, pump tests and treatability studies are run to confirm the practicality or technical feasibility of the remedial alternatives.

Gathering the appropriate information in a timely manner is critical. The Remedial Investigation/Feasibility Study checklist in Appendix B provides a detailed list of the typical data requirements to allow evaluation of alternative remedial options and design a ground water remediation system. Additional discussion of this checklist is provided in Section 3.2.

Key FS and CMS guidance documents are as follows (refer to Appendix A, References, Section A-2.a for full citation):

(USEPA OSWER Directive 9355.3-01, 1988, USEPA 540/R-92-071a, 1992, Driscoll, 1986, USEPA OSWER Directive 9355.4-03, 1989, USACE ER 1165-2-132, USACE EM 200-1-3, USACE EM 1110-1-4000, and USACE EM 1110-1-502).

1.3.2 Design Phase The design phase converts conceptual specifications developed during the FS into construction plans, specifications and design analysis. This phase may require some follow-up data collection. While preliminary construction cost estimates are generated during the FS for purposes of comparison, the design phase provides the detailed pre-bid construction estimate. If the detailed cost estimate is greater than the allowable budget, then design modifications may be initiated to develop a design that is within budgetary constraints. The designer may recognize the need for supplemental information in order to modify the design to allow lower construction or operating costs. Thus, as previously discussed, the process becomes interactive. However, unlike RI/FS investigations, the designer is now in a better position to estimate the benefit and predict the sensitivity of the final design to gathering additional data. This cost/benefit approach should be considered prior to requesting or undertaking activities to gather additional data.

During the design phase it is also frequently found that site specific testing allows replacement of conservative assumptions with real data, resulting in a less conservative (less costly) design. For example, performance of an extended pumping test on a pilot extraction well can allow specification of a narrower range of potential pumping rates and frequently results in specifications of lower influent concentrations than those based on estimates from monitoring wells. Additional detail on design analysis and specifications can be found in USACE ER 1110-345-700.

A design phase checklist is provided in Appendix B. A detailed discussion of the checklist is presented in Section 3.2.

1.3.3 Construction Phase Design Interaction It is crucial to understand that the RI, FS and design phases are interactive. During the FS it is frequently found that additional measurements (e.g. cation/anion analyses) are required to finalize comparison of remedial alternatives. Many design teams have found that during (in) the design and installation phase, and before installing the full scale system, installing a limited number of wells can effectively provide information that would verify that the original design basis for the system is appropriate.

A qualified geologist/geotechnical engineer should provide continuous supervision during construction/installation/development to ensure proper completion of the system. The oversight geologist/engineer should have experience in the installation of well and trench systems. Ideally, the person should have also been involved in the design phase. This person will assist in documenting changes made during the construction phase. This requires effective interpretation of the designer's plans and specifications by the builder. Attention to details

and documentation during the construction phase will result in the installation of the system in a safe and efficient manner. A construction phase checklist is provided in Appendix B. Additional details regarding the construction phase are discussed in Section 3.4.

Some ground water extraction and injection systems are sensitive to the method of construction. The on-site geologist/geotechnical engineer should discuss with the design engineer and project hydrogeologist those aspects of the design which have the potential to cause problems if variations occur during construction. The construction drawings are required to be marked with any changes during the construction and be revised for submittal as "as-built" drawings.

1.3.4 Startup Phase The design phase includes issuance of a preliminary operations and maintenance (O&M) plan which specifies schedules for mechanical maintenance, inspections, recording of data, monitoring of ground water and monitoring of influent and effluent quality. However, actual system performance and details of day-to-day mechanical issues requiring site specific procedures are not accurately known until start-up has occurred.

Therefore, the preliminary O&M plan typically includes a startup plan for intensive evaluation, monitoring and adjustment for a period which can range from weeks to months. Objectives of the startup phase are as follows:

- verify that mechanical systems and controls are operating as per design criteria;
- verify design assumptions;
- measure the actual water balance, capture zones and treatment efficiencies;
- identify design flaws (if any);
- identify unforeseen operational or hydrogeologic issues which may require adjustments to design or operating procedures; and
- develop detailed O&M protocols for maintenance, mechanical operation, monitoring and adjustment of controls to optimize performance.

During the design and construction process, certain operating parameters (design analysis specifications) are proposed to measure performance. If well systems are installed and pilot tested prior to treatment system installation, the information gathered about actual well production and concentrations can be used to modify design as necessary.

Operational parameters can also be verified during the startup phase. Ideally, scientists and engineers originally involved in the design should observe the start-up of the extraction/transport/ injection systems and assist documenting the operation of each system. The team performs shakedown (startup and shutdown) of each system and records operating conditions. This process results in a punch-list of recommendations for modification/ changes to optimize operation. After the shakedown period and after making any modifications/changes to the system, the system is brought into continuous operation. Documentation of all activities and modifications during the startup phase is important to ensure that as-built diagrams and final O&M procedures are updated to reflect adjustment.

A startup phase checklist is provided in Appendix B. Additional discussion of this checklist is contained in Section 3.5.

1.3.5 Operation/Maintenance Phase Operation and maintenance are the continuing activities that are required to achieve successful completion of the project. The two primary objectives of this phase are to monitor system performance (extraction/injection/treatment systems) and to perform routine maintenance in a manner which optimizes operation. Consistent monitoring of system performance and adherence to maintenance schedules is critical. O&M plans should be created by the designer of the well system and supplied to the operator. Plans should begin at the installation of the system and maintained throughout. If data are inconsistently gathered or interpreted, it may be erroneously concluded that there has been a systems failure. Likewise, irregular maintenance can result in poor performance and equipment breakdown.

The key to successful operation of a system is regular evaluation of operating and monitoring data by the on-site operator and the technical team (engineers and hydrogeologists). The O&M plan specifies a regular schedule for communication between the operator and the technical team in which the operator is provided with updated priorities for optimization (e.g. wells at which to maximize pumpage) and in which the technical team is provided with observations regarding mechanical performance. The O&M plan must clearly establish responsibilities and the chain of authorization for changes to the system.

The operation and maintenance checklist to support this activity is provided in Appendix B. A detailed discussion of the checklist is presented in Section 3.6.

1.4 Legal and Regulatory Considerations The designer of a ground water remediation system must be aware of applicable laws and regulations or have the resources available to obtain

information on regulations. Most ground water remediation projects are implemented under regulatory programs pursuant to laws such as CERCLA, RCRA, or similar state programs. A project may be initiated by a lead agency acting under an authorized response program, or a private entity responding to an enforcement action, providing compliance with a permit requirement, or performing a voluntary cleanup. The following paragraphs discuss possible strategies to be used when interfacing with regulating agencies and also highlight some differences between regulatory programs that can affect remedial strategies.

It is a legal question to determine if the Federal agency leading the site cleanup (e.g. USACE) is subject to any laws or regulations which would govern private activities. As a general matter, the doctrine of sovereign immunity prevents Federal or state regulators from applying any law or regulations to Federal agencies in the absence of a clear and specific waiver. Many environmental laws contain some waiver of sovereign immunity, but determining the applicability to particular programs and projects and situations is a matter which must be decided by counsel for the lead agency. There are differences if the work is conducted under the Superfund program for USEPA, the DERP IRP, DERP FUDS, non-DOD Federal agencies or the USACE civil works program. In addition, contractors do not have the immunity of a Federal agency. As a matter of comity, Federal and state substantive standards should always be considered in the design and execution of projects.

1.4.1 Regulatory Agency Interaction The remedial action may be subject to oversight by a Federal or state regulatory agency, usually with the lead agency conducting the work. The site owner/operator may want to be proactive in managing and implementing the project so that cost-effective solutions are proposed to the regulatory agency for their concurrence. The proactive approach is often the better method for managing remediation projects.

Some of the ways to coordinate effectively with regulators are:

- clearly define which agency has responsibility for and authority over the project;
- assign a knowledgeable project manager and regulatory team member;
- consider agency interaction as an integral part of the technical project planning process;

- actively solicit the regulators' comments so that they are part of the project team and avoid taking unnecessary adversarial positions with the regulators;
- communicate frequently and openly with the regulators regarding factual data to maintain good relations and to ensure that all parties are informed of the work plans, schedules, and progress for the remediation effort;
- notify the regulatory agency early regarding problems or issues with the remedial action and propose solutions to obtain their concurrence after internal coordination is completed and an agency position has been established;
- set realistic schedules for project milestones and consistently meet the schedules;
- work directly with the designated agency point of contact when coordination with several regulatory offices is required;
- after consulting with agency counsel, if appropriate, provide suggestions on interpreting regulations, especially those areas where regulators have discretion under the rules;
- prepare legal reports identifying legal regulatory standards, indicating the steps taken to address them, and providing concise summaries of conclusions; and
- provide project status reports (i.e., weekly, monthly, quarterly, etc.) to the regulatory agency and other involved parties informing them of accomplishments, schedule updates, and problems, if any. Consult agency counsel on questions about releases of privileged or confidential information.

These activities should only occur after internal staff of the lead agency, including counsel, have established the agency's position. It is essential to have good lines of communications between all parties involved in the project. The key is to avoid surprises and head off problems before they arise.

1.4.2 System Permitting Requirements The following subsections summarize permitting considerations associated with construction of ground water extraction and injection systems. Consult counsel and lead agency to determine if a permit is actually required, but always consider the substantive standards in deciding on the work to be done.

1.4.2.1 Extraction Unit Permitting and other procedural requirements potentially applicable to the installation of ground water extraction units may include the following:

- permits to construct extraction wells;
- permits to extract ground water (for large extraction units in some states with limited ground water resources);
- access agreements for off-site wells; and
- submittal of well abandonment records when the system is shut down;
- proper license held by well installation contractor.

The process for obtaining an extraction well permit usually includes submittal of an application specifying a design which meets the standards of the state rules. This is followed by receipt of a permit from the regulatory agency. Although not a permitting requirement, most states require that all utility companies be contacted several days before drilling to ensure that underground lines are located and avoided. States may seek to require that work be performed by a licensed driller and that "as-built" logs be submitted to the state following installation. Federal employees are not required to be licensed by the state as long as they meet qualification standards of the employing agency.

Several western states have ground water use laws which require a permit to extract ground water under certain circumstances. Permitting requirements vary widely but may include specification of maximum withdrawal rates, estimation of impact on existing well fields and fees associated with consumptive use of ground water.

Prior to agreeing to any asserted permitting or fee payments, counsel for the lead agency should determine what permit requirements, if any, apply to the project.

Authorization for access will be required prior to installation of wells on property not under the control of the land owner. In this situation, authorization from the off-site property owner should be in the form of a written access agreement. Either agency counsel or designated real estate staff will arrange for appropriate access agreements.

Shutdown of systems at the completion of remediation usually includes abandonment of wells in accordance with state rules. After performing abandonment (which may entail well removal, grouting or well capping), an abandonment record is typically submitted to the state by the licensed driller who performed the operation, after approval by the lead agency. The proper abandonment of wells and exploration borings needs to be

documented and the abandonment completed as soon as it is determined that the well is no longer needed.

1.4.2.2 Transport Unit The ground water transport unit may include extraction pumps, piping, valves, surge tanks, transfer pumps, and injection pumps and piping. RCRA requires frequent inspections of above ground piping for leaks and a double-walled leak detection system for underground piping that transports hazardous waste. Fuels and oils are not classified as RCRA hazardous wastes and are generally exempt from these requirements. The requirements for the design and operation of those units that will manage listed or characteristic hazardous waste are detailed in 40 CFR 264. These rules outline the design, operating and inspection requirements for tanks, piping, controls, and containment systems.

1.4.2.3 Injection Unit Underground injection requirements are governed by the Federal Underground Injection Control program (UIC), which may delegate responsibility for the program to states. An individual state's UIC program generally regulates underground injection of water by permitting and monitoring. Permits may place limits on the quantity and quality of water to be discharged and specify methods to be used to design systems. Contamination limits may be based on the Maximum Contaminant Levels (MCLs) established under the Safe Drinking Water Act, depending on site specific circumstances. Cleanup criteria for treated water may be specified in a Record of Decision under CERCLA, a RCRA Corrective Action Plan, an administrative agreement or other decision document issued or agreed to by the lead agency.

During operation of injection wells, a permittee must implement monitoring and record keeping requirements that are specified in the permit.